COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

HEARING CHARTER
The Investigation of the World Trade Center Collapse:
Findings, Recommendations and Next Steps
October 26, 2005
11:00 A.M.
2318 Rayburn House Office Building

Purpose

On October 26, 2005, at 11 a.m., the House Committee on Science will hold a hearing on the key findings and recommendations of the National Institute of Standard and Technology's (NIST) investigation into the collapse of the World Trade Center (WTC), how building and fire code organizations plan to implement the recommendations contained in that report, and what barriers exist to the development and adoption of stronger building and fire codes.

Witnesses

The following witnesses will address the Committee:

Panel 1:

Ms. Sally Regenhard, Skyscraper Safety Campaign (SSC), New York, NY. The SSC represents families and survivors of the WTC disaster and supports stronger codes and practices for buildings and first responders.

Panel 2:

Dr. William Jeffrey, Director, National Institute of Standards and Technology.

Ms. Nancy McNabb, Director of Government Affairs, National Fire Protection Association (NFPA). NFPA standards are extensively referenced in the NIST recommendations on the WTC collapse.

Dr. James R. Harris, American Society of Civil Engineers (ASCE). ASCE standards are extensively referenced in the NIST recommendations on the WTC collapse.

Mr. Henry L. Green, President, International Code Council (ICC). The ICC is an association of state and local code officials, building mangers, and other parties that collectively maintain the International Building Code (IBC), the most widely used model building code in the U.S. Many of NIST's recommendations reference the IBC.

Mr. Glenn Corbett, Assistant Professor of Fire Science, John Jay College of Criminal Justice, New York, NY. Mr. Corbett is a member of NIST's National Construction Safety Team Advisory Board.

Overarching Questions

The hearing will address the following overarching questions:

1. What are the most important findings and recommendations of the World Trade Center Investigation report?
2. Are the NIST recommendations framed appropriately so that they can be adopted into national model building codes?
3. What are the prospects for the adoption of the recommendations by the code organizations? What is NIST doing to promote this process? What are the possible impediments to their adoption?
4. What lessons were learned from this investigation that could be applied to improve future investigations of building failures?

Background

On September 11, 2001, terrorists crashed two fuel-laden Boeing 767s into World Trade Center (WTC) Tower 1 and Tower 2. While both 110-story buildings withstood the initial impact, the subsequent fires weakened the already damaged columns at the periphery and core of the towers, both of which collapsed. More than 25,000 people were safely evacuated from the towers, however 2,749 people were killed in the disaster. World Trade Center 7, a 47-story office building located adjacent to WTC 1 and 2, was damaged during the disaster and collapsed later that same day.

Immediately following the attack, the Federal Emergency Management Agency (FEMA) and the American Society of Civil Engineers (ASCE) began planning a building performance study of the WTC. The week of October 7, as soon as the rescue and search efforts ceased, an ASCE team under contract with FEMA known as the Building Performance Assessment Team (BPAT) went to the site and began their assessment of why the buildings had failed. This was to be a brief effort, as the study team consisted of experts who generally had volunteered their time. In January 2002, FEMA asked the National Institute of Standards and Technology (NIST) to take over the next phase of the investigation of the collapse essentially to build upon the BPAT recommendations and conduct a more thorough investigation of the events leading to the collapse.

The Science Committee held two hearings in 2002 on the WTC collapse, one on March 6 and the other on May 1. The March 6, 2002, hearing focused on how the Federal Government investigates catastrophic building failures, and what had been learned from the collapse of the WTC 1, 2 and 7. Concerns raised at the hearing included the lack of any specific Federal authority, protocols, or funding for investigations of this kind. Concerns were also raised regarding the timing of the BPAT deployment (almost a month after the towers fell), its access to the site and building records, premature disposal of evidence, and FEMA's lack of regular communication with the public about the investigation.

The BPAT released its report at the May 2002 hearing. The hearing also reviewed plans for NIST to begin a more comprehensive investigation in view of the criticisms of FEMA, and provided a forum to discuss proposed legislation to give NIST the authorities necessary to conduct such an investigation. The BPAT report highlighted potential reasons for why the two towers, almost identical in design, performed differently under the stresses of the disaster. It also identified critical features that enabled so many to evacuate, and the design elements that may

have played a role in the collapse and prevented people above the impacts from being able to exit the buildings. However, witnesses commented that, without a more sophisticated analysis of the evidence, no conclusions could be drawn that could be used to recommend improvements in building and fire codes to prevent future loss of life.

Also at the May 2002 hearing, the witnesses commented favorably on draft legislation being prepared by the Science Committee, based on the authorizing legislation for the National Transportation Safety Board (NTSB) to enhance NIST's existing authority to investigate building failures. On May 9, 2002, the National Construction Safety Team Act (NCST - H.R. 4687) was introduced by Congressman Sherwood Boehlert and Congressman Anthony Weiner. The NCST was signed into law on October 1, 2002. Under the Act, NIST is authorized to appoint a national construction safety team to determine the causes of a building's failure, evaluate the technical aspects of evacuation and emergency response, and "recommend, as necessary, specific improvements to building standards, codes, and practices based on the findings," and propose any research needed to improve building safety and emergency response procedures." The law gives NIST subpoena power to ensure that all material it has access to all evidence to support an investigation, but the results of such investigations cannot be used as evidence in any subsequent litigation.

On August 21, 2002, NIST announced the appointment of a national construction safety team to investigate building and fire safety in WTC 1, 2, and 7. The project was funded through FEMA, and cost $16 million.

Building and Fire Codes

Building and fire codes are established and enforced by state and local governments, which generally base their codes on national model codes that are written by private non-profit standards development organizations (SDOs). These organizations are generally are made up of members – individuals and groups – that have an interest in construction. Generally make their money through membership payments and selling their codes.

Building and fire codes and standards are technical descriptions of constructions, materials, installations, equipment, or practices designed to achieve specific results, such as safety or strength. Standards are very specific guidelines that describe single elements of construction or safety. For example, a "fire rating" is a standard that describes the amount of time a construction element such as a beam can be exposed to a typical fire before it breaks or fails. Other examples of building standards include hallway or stairwell widths deemed necessary to evacuate a certain number of people in a certain amount of time, or the type of steel needed for a beam to support a certain amount of weight. NIST does not write building or fire codes, but does participate in the discussions and provides technical guidance to the standards development organizations.

The most widely-used model building code in the U.S. is the International Building Code (IBC). It is currently the basis of the codes in 45 states and the District of Columbia. The IBC is developed and owned by the International Code Council (ICC). The ICC's members consist of state and local building code officials, building owners and managers, and private sector participants from construction and other industries. ICC's members are concerned with safety, but also with cost and other economic considerations, and these are reflected in the outcomes of the code meetings. The IBC is regularly updated in a deliberative, committee-driven process that

takes about eighteen months. The deadline for submitting proposed changes to the IBC, which begins the next eighteen-month cycle, is March 24th, 2006.

The National Fire Protection Association (NFPA), which develops many standards related to fire safety, recently produced an alternative model building code, NFPA 5000. Experts say that implementing NFPA 5000 may be more expensive than the IBC but may result in a greater level of safety. NFPA's membership is different from that of the ICC, with strong representation by fire protection officials and fire equipment manufacturers. NFPA 5000 has not been widely adopted, but individual NFPA standards are widely used in fire codes.

The NIST Investigation

NIST's Building and Fire Research Laboratory (BFRL) carries out research in fire science, fire safety, structural, mechanical, and environmental engineering. It is the only federal laboratory dedicated to research on building design and fire safety.

The goals of the NIST WTC investigation of the WTC disaster were to investigate the building construction, the materials used, and the technical conditions that contributed to the outcome of the WTC disaster to serve as the basis for:

- Improvements in the way buildings are designed, constructed, maintained, and used;
- Improved tools and guidance for industry and safety officials for safer buildings and better coordination in emergencies;
- Recommended revisions to current building codes, standards, and practices' and
- Improved public safety.

The specific objectives were to:

1) Determine why and how WTC 1 and WTC 2 collapsed following the initial impacts of the aircraft
2) Determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response;
3) Assess what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1, 2; and
4) Identify areas in current building and fire codes, standards, and practices that warrant revision.

To meet these goals, NIST assembled a team of in-house experts and outside specialists, totaling about 200 people. The team compiled and reviewed tens of thousands of documents, photographs, and films, interviewed over a thousand people who had been on the scene or who had been involved with the design, construction, and maintenance of the WTC; analyzed 236 pieces of steel taken from the wreckage; performed laboratory tests, and performed computer simulations of the sequence of events that happened from the instant of the aircraft impact to the initiation of collapse for each tower. In addition, NIST held several public meetings in New York City to report on the status of the investigation and solicit comments and additional information that might further the investigation.

In September, 2005, NIST released its draft *Final Report of the National Construction Safety Team on the Collapse of the World Trade Center Towers* for public comment. A copy of the executive summary of the report is attached. This report summarizes the findings of the investigation and includes thirty recommendations to improve the safety of tall buildings, occupants, and emergency responders. NIST will publish its final report within the next two weeks.

NIST Findings

The NIST investigation confirmed and expanded upon several of the findings by the initial FEMA BPAT study. When built, WTC 1 and WTC 2 were unlike any other skyscrapers in existence at the time, both in terms of their height and innovative structural features. These consisted of a "frame-tube" system of exterior columns on the four faces of the towers, linked to a core of columns by light-weight trusses that supported the floors. In spite of their innovative design, WTC 1 and 2 met or exceeded the requirements of the New York City building codes.

The NIST investigation determined that although the aircraft did considerable damage to the principal structural components of WTC 1 and 2, the towers were inherently robust, and would have remained standing were it not for the dislodged fireproofing which exposed the central columns to the multifloor fires. In each tower, a different combination of impact damage and heat-weakened structural components contributed to the abrupt structural collapse. The fire safety systems in WTC 1 and 2 met or exceeded current practice at the time the towers fell, but played no safety role on September 11th because the water supplies and electrical systems were damaged by the aircraft impact. In WTC 1, the aircraft destroyed all escape routes, and 1,355 people were trapped in the upper floors when the building collapsed. In WTC 2 where evacuation had already commenced, about 3,000 got below the impact zone before the second plane crashed. One stairwell remained passable for a short period of time and eighteen people evacuated through the impact zone. The remaining 619 people perished. WTC 2 collapsed before WTC 1 because the aircraft did significantly more damage to the central columns and the fires were concentrated on the East side of the building, rather than moving around as they did in WTC 1.

Major Issues Addressed in the NIST WTC Recommendations

NIST's recommendations fall into eight groups:

- Increased Structural Integrity,
- Enhanced Fire Resistance of Structures
- New Methods for Fire Resistance Design of Structures
- Improved Active Fire Protection
- Improved Building Evacuation
- Improved Emergency Response
- Improved Procedures and Practices, and Education and Training.

These recommendations include many references to specific SDOs to modify or, in some cases, completely overhaul those standards that apply to building construction, evacuation, testing, and fire safety. NIST's recommendations also refer to less specific audiences such as building managers, building occupants, property developers, and first responders to develop procedures and best practices to protect building occupants.

The following highlights some of the key issues referenced by NIST in its recommendations:

- **Increased Structural Integrity**

The NIST investigators found that the existing methods of calculating the effect of wind and other stressors on tall towers produced markedly different results among the different tests, leading them to question whether these tests had a basis in fact and needed to be re-designed. NIST's report also focuses on the concept of "progressive collapse", where the weakening of one structural element contributes to the weakening of others. NIST raises the question of whether the current practice of testing individual building components such as columns and floor trusses gives an accurate estimate of the resilience of an entire building assembly to fire, wind, and other stressors. NIST recommends that a "structural frame" approach to fire resistance ratings be developed by the structural standards groups such as ASCE. However, progressive collapse is not well understood, and it may take time for these groups to produce a standard and describe the appropriate tests against which to judge whether structures are prone to progressive collapse.

The recommendations pertaining to structural integrity and design are directed largely at ASCE-7, and specifications developed by the American Concrete Institute (ACI) and the American Institute of Steel Construction (AISC), as well as NFPA, and urge that the latest version of these standards and specifications be adopted by the ICC and NFPA into their model building codes.

- **Improved Fire Resistance of Structures and Fire Protection**

Over the years, across the United States, there has been a gradual reduction in rigor of building codes of fire rating requirements i.e. how long something such as a steel column can remain exposed to a fire before breaking or deforming. There has also been a decrease in the compartmentalizing requirements for working and living spaces. Large compartments in buildings allow more air to flow to fires and allow fires to spread faster. Large compartments, however, means more floor area, more tenants, and more rent for the building owner. A lower fire rating requirement allows the use of lighter and less material in construction. The loosening of these restrictions has been compensated for increasing requirements for sprinkler systems, which have been shown to be effective in quenching typical office fires. On September 11th however, the sprinkler systems were disabled, and even in typical fires, sprinkler systems do not always work. NIST recommends greater redundancy in sprinkler systems, and more compartmentalization to restrict air flow to fires. These recommendations apply to several standards developed by NFPA.

The reduction in fire ratings has also been compensated by the use of spray-applied fire resistive materials (SFRM) on structural components. This was the foam that was applied to the columns and trusses of WTC 1 and 2 as fireproofing. After the 1993 WTC terrorist bombing, it was recommended that the spray-on fire protection on the steel components of the towers be thickened. NIST emphasizes that, were it not for the dislodging of the fireproofing from the structural steel when the aircraft flew into the towers, WTC 1 and 2 would likely have withstood the subsequent fires. The foam on WTC 1 and 2 was shaken or blown off around the cores and peripheral columns on several floors in both Towers on September 11th, meaning the columns reached critical temperatures much faster then they would have normally. NIST recommends that the performance of this type of fireproofing needs to be better understood, particularly its response to shock, aging, and method of application, and new coatings should be developed.

NIST notes in its report that both the IBC and NFPA 5000 model building codes have since changed their fire rating requirements for buildings over 420 feet from two hours to four. The report also says, however, that the technical basis for fire ratings is not strong, particularly since the typical contents of offices, and construction materials, have changed in the last 100 years. NIST recommends a comprehensive review by all fire-related SDOs of fire testing procedures to ensure that fire ratings are meaningful. Structural fire resistance is closely tied to the outcomes of work on the structural frame approach for large buildings, which NIST advocates in its report while recommending an extensive re-evaluation by national building code committees (ICC and NFPA) of the dynamics of fire, evacuation, and emergency response for skyscrapers to determine what fire ratings are needed for tall buildings. In the case of re-evaluating the tests steel and concrete assemblies, this could be an expensive proposition. A typical full-scale fire test costs $30,000 or more per test, and to validate a new test, experimental tests must to be run several times. It is not clear who should be conducting these tests.

- **Full Evacuation of Large Buildings**

After the 1993 terrorist bombing of the WTC site, it took four hours to evacuate everyone from WTC 1 and WTC 2. The standard evacuation plan for skyscrapers does not usually anticipate such a mass egress: fire-related evacuation plans assume that occupants "evacuate in place" to higher and lower floors while first responders fight the fire. Although this approach may change as a result of the events of September 11th, it may still be the most practical and safe procedure for typical skyscraper fires. Skyscraper elevators in the U.S. are not generally fireproof, nor are they intended to be used for mass evacuation. Full evacuation via stairwells takes a long time. On September 11th, with all elevators out of commission, it would have taken hours for firefighters to ascend to the affected floors to fight the fires, or assist survivors down the stairs. This fact has provoked some re-thinking of how elevators should be designed and used for emergency purposes.

WTC 1 and 2 had three stairwells each, centered at the core of the buildings. When the aircraft crashed, these stairs were destroyed. The NIST investigation found that about six percent of the people in the towers had health problems or disabilities that made taking the stairs difficult. Overall, it was found, people evacuate buildings twice as slowly as generally thought. NIST recommends structural hardening of elevators for use in large-scale emergencies, and that stairwells be spaced further apart, although it does not say by how much. NIST also recommends that stairwells should be widened to allow more people to descend as well as to allow counter flow from first responders going up the stairs. Most of the recommendations apply to NFPA 101, and the *National Model Building and Fire Codes* of the ICC.

- **Communications and Emergency Response**

For the approximately 1,000 emergency responders on the site on September 11th, this was the largest disaster they had ever experienced. Communications networks at the site were destroyed, and portable communications devices such as walkie-talkies and cellular phones were overwhelmed as dozens of first responders attempted to talk at the same time. Walkie-talkies performed inadequately, or otherwise failed to function inside the steel-concrete construction of the towers. There was no interoperability between the New York Police Department and the New York Fire Department equipment. Although there had been significant upgrades to the fire monitoring and communications infrastructure in the WTC Complex after the 1993 terrorist bombing, incident command centers established inside the two towers by first responders were still unable to provide a sufficient assessment of the situation, or monitor and relay information

to other first responders at the site for proper coordination of their activities. First responders commented later that viewers watching the disaster on television had a better grasp of the scope and nature of the crisis than did anyone at the WTC site.

NIST's recommendations on improved emergency response apply mostly to NFPA standards, but also extend to the Department of Homeland Security, and state and local jurisdictions, and first responders. NIST emphasizes that systems need to be effective for large-scale emergencies and able to funding in "challenging radio frequency environments", as well as better procedures for integrating information from multiple sources and coordinating a unified response among different agencies and departments.

Additional Issues

- **Follow-up funding is limited**

In many instances, NIST has recommended research and testing to determine whether and how changes in building codes should be made. It is not clear this effort will receive the commitment for funding it requires. In order to implement many of NIST's recommendations, a lot of research and collaboration with SDOs and stakeholders will have to be done to provide a scientific and technical basis for the standards changes needed to meet those recommendations. NIST requested $2 million in additional funds for FY 2006 for codes and practices for buildings and first responders, but the FY 2006 appropriation has not yet been finalized. If adequate funding for NIST's research efforts is not provided, it is unclear what progress will be made on implementing those recommendations that need scientific research to be implemented.

- **Future building investigations**

It is unclear what role NIST will play in investigating future building failures. FEMA received heavy criticism at the Science Committee hearing March 6, 2002, for shortcomings in the way in which it conducted the investigation of the collapse of the World Trade Center. The passage of the National Construction Safety Team Act was supposed to address these shortcomings by creating the authority to investigate building failures at NIST and providing NIST with subpoena power to obtain whatever evidence it needed to complete investigations. However, in the years since September 11th, although several building failures have occurred, Hurricane Katrina being the most recent event causing structural failures, NIST has not invoked the NSTC Act to launch investigations, but rather has been called in under another agency: FEMA in the case of Katrina. NIST does not have a source of funding dedicated to pay for such activities and is apparently reluctant to act independently. Outside observers note that NIST is a research institution and may not be culturally suited to conduct investigations as does the NTSB, upon which the NCST Act was based, or the Chemical Safety and Hazards Investigation Board.

Questions for the Witnesses

Ms. Sally Regenhard, Skyscraper Safety Campaign

I invite you to open the hearing with a five-minute statement that outlines the views of the Skyscraper Safety Campaign on the investigation, its findings and the next steps that should be taken.

Dr. William Jeffrey, Director, National Institute of Standards and Technology.

In your testimony, please briefly describe the most important findings and recommendations of the NIST investigation of the World Trade Center collapse and answer the following questions:

1) What specific steps is NIST taking to ensure that its recommendations are incorporated into model and local codes? What barriers has NIST confronted or does it expect to confront as part of that process and how do you plan to overcome those barriers? What past successes can NIST draw on as part of this effort?

2) Some experts have criticized the recommendations – some arguing that they are too general and therefore hard to translate into codes, and others arguing that they are too detailed and will needlessly increase building costs. How do you respond to these criticisms?

3) What lessons have you learned in carrying out this investigation that could be applied to future investigations, including the ones being undertaken in the wake of Hurricane Katrina?

Ms. Nancy McNabb, Director of Government Affairs, National Fire Protection Association (NFPA).

In your testimony, please briefly describe the process by which NFPA writes codes and answer the following questions:

1) Does NFPA support the recommendations of the NIST study? Why or why not?

2) What specific steps will NFPA be undertaking to determine whether and how to incorporate the NIST recommendations into its codes? How long should that process take? What will be the greatest barriers in the process?

3) What specific actions should NIST be taking to help code organizations incorporate its recommendations? Are the recommendations framed in a way that facilitates their adoption by code organizations or are they too general or too specific?

Dr. James R. Harris, American Society of Civil Engineers (ASCE). .

In your testimony, please briefly describe the process by which ASCE writes codes and answer the following questions:

1) Does ASCE support the recommendations of the NIST study? Why or why not?

2) What specific steps will ASCE be undertaking to determine whether and how to incorporate the NIST recommendations into its codes? How long should that process take? What will be the greatest barriers in the process?

3) What specific actions should NIST be taking to help code organizations incorporate its recommendations? Are the recommendations framed in a way that facilitates their adoption by code organizations or are they too general or too specific?

Mr. Henry L. Green, President, International Code Council (ICC).

In your testimony, please briefly describe the process by which ICC writes codes and answer the following questions:

1) Does ICC support the recommendations of the NIST study? Why or why not?

2) What specific steps will ICC be undertaking to determine whether and how to incorporate the NIST recommendations into its codes? How long should that process take? What will be the greatest barriers in the process?

3) What specific actions should NIST be taking to help code organizations incorporate its recommendations? Are the recommendations framed in a way that facilitates their adoption by code organizations or are they too general or too specific?

Mr. Glenn Corbett, Assistant Professor of Fire Science, John Jay College of Criminal Justice, New York, NY.

1) What are the most important findings and recommendations of the NIST World Trade Center Investigation report?

2) Some experts have criticized the recommendations – some arguing that they are too general and therefore hard to translate into codes, and others arguing that they are too detailed and will needlessly increase building costs. What is your view of these criticisms?

3) What are the prospects for the adoption of the recommendations by the code organizations? What should NIST and the code and standards groups be doing to promote this process?

4) What lessons were learned from this investigation that could be applied to improve future investigations of building failures?